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A constructivist approach towards a general definition of biodiversity

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Abstract—Biodiversity sciences witness a double dynamic. Whereas the need for interdisciplinary approaches is increasingly appreciated, most disciplinary studies are still confined to developing operational, discipline-specific indices. We show that a reassessment of the general notion of biodiversity is needed to clarify this situation. We advocate a new approach, according to which the main usefulness of this notion is not to capture quantitatively biological objects or processes, but to organize meaningful and coherent interdisciplinary interactions by constructively criticizing disciplinary studies. We apply this approach to ecological-economic models, in the hope of launching more fruitful critical dialogs between economists and biologists.

Keywords: surrogates, politics and policy, philosophy, economics, ecosystem management

1. Introduction

"Biodiversity" is a new term introduced in the 1980s (Wilson & Peters 1988). Its use has increased tremendously (Loreau 2010) since the Convention on Biological Diversity (CBD) in 1992, in which "biodiversity", as shorthand to "biological diversity", is defined as referring to "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems" (UN Conference on Environment and Development, Rio de Janeiro, 1992, Convention on Biological Diversity, Article 2). Several reformulations of this definition have been introduced in the literature, two prominent example being Groves et al. (2002)'s definition of "biodiversity" as "the variety of living organisms; the biological complexes in which they occur, and the ways in which they interact with each other and the physical environment", and Purvis & Hector (2000)'s definition of "biodiversity" as "the sum total of all biotic variation from the level of genes to ecosystems". All these definitions are markedly similar, especially in that they are anchored in the notions of diversity, variety and variability, in effect taken as synonyms. Therefore, in the remainder of this article, we will talk about "the CBD definition and its reformulations" to collectively refer to all these definitions. Most biologists content themselves with such definitions (Mace et al. 2012), used as a basis of a shared tacit understanding (Schläpfer et al. 1999). They usually skip from abstract discussions on the general definition of biodiversity directly to technical discussions on discipline-specific indices of biodiversity. Some ecological studies thus approximate biodiversity by species richness (Fleishman et al. 2006), sometimes weighted by relative abundance (Colyvan et al. 2009). Other studies, purporting to shed light on other aspects of biodiversity, favor more complex indices, mainly based on functional traits (Mason et al. 2003, Petchey & Gaston 2002), phylogenetic distances (Faith 1992) or habitat structure (Noss 1990). As these various approaches improve their respective methodologies, the various indices become more sophisticated and better-adapted to capture specific aspects of biodiversity. In that sense, the biological literature witnesses a specialization of approaches to biodiversity (Petchey et al. 2009, Schleuter et al. 2010). At the same time, however, many authors emphasize that protection, monitoring and valuation of biodiversity raise multifaceted societal, economic, political and scientific issues, thereby requiring a new integrative, interdisciplinary approach (Tassy 2006, Maris 2010, Loreau 2010, Meinard 2011, Meinard & Grill 2011).

Our aim in this article is not to add our piece to an already long list of reviews and historical presentations of these trends, but rather to investigate whether a general definition of biodiversity can reconcile these two trends. Indeed, although they point in divergent directions, specialization and integration need not contradict each other: a general definition of biodiversity should allow the integrative, interdisciplinary approach to encompass and combine the various results of the specialized studies, each focused on its own operational index of biodiversity. Such a general definition would be a clearly articulated overarching concept of biodiversity, broad enough to encompass all the various specialized approaches, but at the same time explanatory enough not to trivialize the integrative, interdisciplinary approach. Do the CDB definition and its reformulations fulfill this requirement? Here we advance a negative answer to this question, and we suggest a new, alternative approach towards the general definition of biodiversity.

Indeed, although the CBD definition and its reformulations certainly seem unequivocal at first sight, it turns out that they can be understood in markedly different fashions, depending on the method used to clarify and elaborate them. These definitions therefore do not guarantee that, when using the term “biodiversity” in collaborations with colleagues from other disciplines, we can take it for granted that we understand each other. This defect undoubtedly makes these definitions unsuitable for the purpose of integrating different disciplines by interdisciplinary interactions. The classical approaches to clarify and elaborate the CBD general definition and its reformulations, which will be explored in more detail in this article, can be grouped into three types:

- The first approach holds that the CBD definition and its reformulations are clear and unequivocal because the notion of diversity, in which they are anchored, is itself clear and unequivocal. We call this the "ordinary approach" because it is based on the meaning of the term "diversity" in the ordinary, everyday language. The other two approaches admit that the latter meaning is more difficult to ascertain than it might seem at first sight, and that this first approach is therefore trivializing.
- The second approach holds that "biodiversity" can be implicitly defined, but that any such definition is doomed to critically depend on arbitrary choices. This approach thus suggests that trying to find a general definition of biodiversity is a futile, useless exercise, because countless different, but equally acceptable, definitions can be carved out. We call it the "conventionalist approach" because, in the philosophical jargon, such arbitrary choices are called "conventions" (Lewis 2002).
- The third approach, which can be called "the unit-and-differences" approach, has been prominently developed by Maclaurin & Sterelny (2008). This approach develops a much more ambitious vision, according to which our understanding of the notion of biodiversity should be based on an account of a project that plays a crucial role in the scientific endeavor: the one of identifying causally relevant units, differences and dissimilarities.

These three approaches are markedly different and, as their more precise presentation will illustrate, they can have markedly different implications. It is therefore necessary, in order to assess whether the CBD definition and its reformulations can reconcile the two trends portrayed above, to start by assessing the credentials of these three approaches. We will argue that the first two approaches are unsatisfactory, and that the third one, although more powerful, misses a crucial dimension of the importance of the notion of biodiversity in the current scientific debates. In order to make up for this lacuna, we advocate a forth, “constructivist approach” (Habermas 1983, Gadamer 2004), according to which the meaning of the term “biodiversity” emerges from a task progressively articulated by developing interdisciplinary studies. In this theory, biodiversity is not a pre-existing entity, but a dynamic concept built by the very fact that several disciplines coherently work together.

We should emphasize at the outset that this approach does not purport to provide for a new measurable concept. In this approach, the general notion of biodiversity is not useful for specific scientific experiments, calculations or measures (discipline-specific biodiversity indices are the relevant tools for these purposes). However, the general definition of biodiversity, suitably determined, is a useful concept to organize interactions between disciplines and to ensure that the results of each biodiversity discipline can make sense for the other biodiversity disciplines. This role, unfortunately neglected by the other approaches toward the definition of biodiversity, can be of major importance in the current context of the implementation of the agenda of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). We illustrate how the general notion of biodiversity can play this role with an example: we show that the constructivist approach can shed light on the true meaning of the results of ecological-economic modeling.

2. The three classical approaches towards a general definition of biodiversity

Although the literature on discipline- and problem-dependent indices of biodiversity is extensive, after early skeptical attempts (Ghilarov 1996, Takacs 1996) the issue of the general definition of biodiversity has not been subject to many in-depth conceptual analyses. It is therefore useful to discuss the three classical approaches introduced above in more detail.

2.1. <u>The ordinary approach</u>

This approach is predicated on the idea that a general definition of biodiversity can be based on the notion of diversity, because the latter is a basic, simple and unequivocal notion. Although it is implicitly accepted by many biologists, this approach has been rigorously formalized only outside the ecological literature, by axiomatic economists (Bervoets & Gravel 2007, Bossert et al. 2003, Gravel 2008, Klemish-Alhert 1993, Nehring & Puppe 2002, Weizman 1992) concerned to identify a general definition of “diversity”, applicable to all kinds of objects.

Given that the term “diversity” belongs to the ordinary language and seems to be simple and unequivocal, it is natural to try to delineate its meaning by enlisting the properties naturally associated with it. Axiomatic economists therefore start with lists of properties supposedly naturally associated with the idea of diversity, from which they deduce definitions of “diversity”. For example, Pattanaik & Xu (1990, 2000) claim that the properties inherent to diversity are reflexivity, transitivity, cardinality, independence, monotony and indifference (see Table 1 for formal definitions of these properties), and they show that richness is the only property jointly satisfying them. Strictly speaking, what they demonstrate is that: if the meaning of the term “diversity” is given by the properties above, then “diversity” is a synonym of “richness”.

Unfortunately, the identification of the relevant properties turns out to be less evident than it seems. The monotony property provides a striking illustration of this idea, since the question whether it should be considered a property inherent to diversity admits different answers depending on the context. If formulated in terms of species, the idea that monotony is a constitutive property of diversity roughly means that adding a species to a sample that does not already contains it will always increase the diversity of the sample. This is intuitively compelling in some contexts but, interestingly, some widely used measures of diversity, like the Shannon diversity index (Magurran 2004), do not satisfy this property. Indeed, this measure has another intuitively compelling property, which happens to be incompatible with monotony: it decreases when a species is added to a sample, if the population of this species is markedly different from the populations of the other species in the sample (which is quite often the case in real biological systems, for examples when invasive species invade native communities). To take another specific example, Bervoets & Gravel (2007) argue that another idea is naturally associated with the notion of diversity. This idea is that, although most of the time one can order differences between species (one can tell, for example, that the difference between a human being and a pine is greater than the difference between a pine and a spruce), it is sometimes impossible to tell how greater one difference between two species is than another difference (although it is possible to quantify how greater the difference in DNA sequences between a human being and a pine is than the one between a pine and a spruce, it is impossible to make similar judgments when it comes to comparing overall differences). But Bervoets & Gravel (2007) demonstrate that, although this idea is arguably intuitively associated with this idea of diversity, none of the usual diversity indices used in the literature satisfy it; they show that the only conceivable index satisfying it is an otherwise counterintuitive index that orders samples in terms of diversity on the sole basis of the differences between the two most different species in each sample. In other words, what they demonstrate is that, although this idea seems to be naturally associated with the notion of diversity in some contexts, a more precise investigation shows that it is impossible to adhere to this idea consistently. Similarly, for each and every property claimed to be intuitively inherent to diversity, intuitive examples can be found to argue that it is not (and a substantial part of the axiomatic literature actually consists in exploiting such examples).

The axiomatic literature on diversity has thereby produced a whole series of axiomatic definitions of diversity, each equating the putative property diversity with different conjunctions of elementary properties (Gravel 2008, Meinard 2011). These various analyzes are all based on intuitively compelling examples, but their respective results are markedly different from one another (Aulong et al. 2005). This would not have disastrous implications, if the whole axiomatic approach to diversity were not based on the assumption that diversity is a basic, simple and unequivocal notion. The very fact that axiomatic studies do not clearly converge on a simple, unequivocal analysis of the notion of diversity therefore demonstrates that the fundamental postulate of this approach that diversity is a basic, simple and unequivocal notion, is unwarranted.

This failure of the ordinary approach therefore shows that, apart from vague intuitions, there is no firm criterion to decide which properties are really inherent to the notion of diversity (and the same is obviously true of the notion used as synonyms of "diversity" in the CBD definition and its reformulations, like "variety", "variability"). In other words, although the term "diversity" seems clear and unequivocal, it is in fact deeply ambiguous. As a consequence, all the definitions of biodiversity that—like the CBD definition and many of its reformulations—contain the term "diversity" are doomed to be ambiguous themselves.

2.2. The conventionalist approach

This alternative approach has been prominently developed by Sarkar (2002, 2005). Sarkar does not explicitly criticize the ordinary approach, but his emphasis on the need to develop a radically new approach, rejecting supposedly transparent terms like "diversity" or "variability", shows that he implicitly admits that the CBD definition and its reformulations based on ordinary terms are unsatisfactory.

At the core of his alternative approach lie two questionable postulates. P1: Biodiversity is confined to conservation biology. P2: Conservation biology is only concerned with ranking series of natural areas in terms of priority for conservation. The fact that Sarkar admits these postulates (at least for the purpose of defining "biodiversity") is clearly stated in his contention that "biodiversity should be ... defined as what is optimized by the place prioritization procedures" (Sarkar 2005, p. 180), the latter procedures in turn being the pivotal tool of his "consensus view of conservation biology" (see his Table 6.1.1, page 153, and more generally his whole chapter 6). Sarkar then defines different "surrogates" (Heyer et al. 1994) representing biodiversity in various ways (Fig. 1A). "Estimator surrogates", such as species composition, are components of biodiversity that can be directly measured. These estimator surrogates are estimator variables having "true surrogates" as their objective variables, and true surrogates are loosely defined as having biodiversity as their "intended objective". Associated with postulates P1 and P2, these definitions of surrogates allow Sarkar to claim that any place prioritization algorithm based on estimator surrogates implicitly defines biodiversity.

The construction and implementation of such algorithms always involves making choices that cannot be entirely justified. For example, when one chooses between using species richness or sub-species richness as index, although this choice can be partially justified, it also involves a modicum of arbitrariness. Since different algorithms can rank differently the same series of places, this approach therefore yields a highly unstable definition of biodiversity. This instability is relatively innocuous so long as one accepts the postulates of his approach. However, it appears to be a serious problem as soon as one realizes that these postulates, especially P1 (that biodiversity is confined to conservation biology), are hardly credible. Indeed, the term "biodiversity" has recently undergone a striking interdisciplinary expansion and is now a key-notion in several other biological disciplines, especially in functional ecology (Loreau et al. 2002, Hooper et al. 2005) and biogeography (Brooks & McLennan 2002). Its economic (Heal 2004), social and cultural importance is also increasingly recognized, and biodiversity has become a crucial theme in economics of ecosystem services

(Perrings et al. 2009) and ethics (Maris 2010). One could therefore draw a surrogacy structure for each relevant discipline neglected by Sarkar, each leading to another implicit definition of biodiversity. MacLaurin & Sterelny (2008) take Sarkar's approach to be generalizable in this way, which they summarize by saying that "Sarkar uses 'biodiversity' to mean whatever we think is valuable about a biological system" (p. 8). We would more precisely say that according to Sarkar's generalized approach, in each and every case where something is deemed valuable in a biological system, this something can be used to produce a new, idiosyncratic definition of "biodiversity" (Fig. 1B). In this approach, trying to find a general definition to "biodiversity" is therefore futile, because each trial is doomed to produce another definition, neither better nor worse than former ones. For example, the application of a given prioritization algorithm for conservation purposes to a given series of places would produce a first definition, the application of a different procedure to make a public choice in the management of fisheries would give a second definition, and the application of another approach to a carbon storage scheme would give a third definition. The three definitions, associated as they would be with different reasons for valuing the corresponding biological systems, would equally qualify as definitions of biodiversity.

The deflationary flavor of this approach would certainly make it hardly credible for most biologists. However that might be, from the point of view of our inquiry in this article, the main problem with this conventionalist approach is that it cannot explain the nature of the link between the various specialized biodiversity disciplines.

2.3. The unit-and-differences approach

Maclaurin & Sterelny (2008) have developed an original approach (to some extent prefigured in Gaston 1996), which we call, borrowing their own phrase, the "unit-and-differences" approach. Their argument can be summarized in four steps:

(1) “In general, the diversity of a system will depend both on the number of distinct elements in the system and on their degree of differentiation.” (p. 9)

(2) The identification of the distinct elements of a system and their differences is not arbitrary from a scientific point of view. On the contrary, it is “central to any attempt at understanding a domain ... because a good system of classification links diagnostic criteria for identification with similarity in causal profile.” (p. 10) In other words, assuming that scientific theories are mainly devoted to identify and characterize causal relations, their capacity to fulfill this central aim is crucially linked with their capacity to identify the distinct elements of a system and their differences.

(3) Since “history, environment and chance ... affect their causal profile in different ways ... it turns out that there is no single system for identifying all the similarities and differences between biological systems that matter.” (p. 10)

(4) The characterization of any given biological system in terms of biodiversity therefore depends on the theoretical approach chosen to study it, which in turn depends on “the instrumental and explanatory purposes of particular groups of scientists” (p. 21)

From this reasoning, Maclaurin & Sterelny conclude that biodiversity is “a natural magnitude (or magnitudes) of biological systems” (p. 6), that cannot be reduced to “a single natural property” (p. 7) but for which “a phylogenetically informed species count is a good general indicator or surrogate” (p. 7). On the face of it, this definition seems quite similar to the general definitions used by most biologists (see the examples cited in the introduction, and in Gaston 1996). It differs, however, in that: (1) It explicitly emphasizes that the search for a unified measure is hopeless (which is why this approach is characterized as “pluralist” by its authors). And (2), it explains this exclusion of a unified measure by an epistemological account of the reason why different scientific explanations of a given biological system can differ in the units, differences and dissimilarities that they deem important (“we need to identify diversity differently, for different explanatory projects", Maclaurin & Sterelny 2008, p. 8).

This approach is arguably the most promising of the current approaches since, contrary to the other two, it is not marred by any obvious flaw. However, we will argue in the following section that it shares with the other two approaches two unwarranted tenets. And we will argue, in section 4, that relaxing these two tenets allows developing an alternative approach that we believe is even more powerful than the unit-and-differences one.

3. A new constructivist approach toward a general definition of biodiversity

The first step to develop a new fourth approach is to realize that the logic of these classical approaches is based on two hidden unsupported tenets.

3.1. Two tenets presupposed by the three classical approaches

The first tenet (T_1) is the presupposition that the definition of a term, understood as what we are trying to capture by our act of defining it, cannot be determined by this act itself. In short, the definition of a term always preexists our act of defining it. The second tenet (T_2) is that finding the definition of a term is a matter of identifying an entity, in the objective world, to which the term would refer. Here "entity" should be understood broadly, encompassing not only things and objects, but also processes, properties and attributes. In the philosophical literature, the two tenets T_1 and T_2 constitute the "semantic postulate" (Tughendhat 1976, Meinard 2011). First, let us show that the three classical approaches presented above are indeed based on these tenets. Then we will show that, although these two tenets seem to be self-evidently valid, convincing counter-examples show that they are false.

Most obviously, the ordinary approach is predicated on T_1 and T_2. Indeed, in this approach, there is such a thing as the preexisting meaning of the term “diversity” (T_1), given by the alleged fact that this term would refer to a preexisting property or list of properties (T_2). Similarly, as quoted above, the unit-and-differences approach explicitly claims that “biodiversity” refers to “a natural magnitude (or magnitudes) of biological systems” (Maclaurin & Sterelny 2008, p. 6), and therefore explicitly assumes T_1 and T_2. Although it does not accept it so openly, the conventionalist approach is also demonstrably predicated on T_1 and T_2, since it is based on an inference whose validity is predicated on T_1 and T_2. Indeed, from the premise (P_c) that various entities emerge as what is optimized by various algorithms, the conventionalist approach concludes (C_c) that general definitions of biodiversity are doomed to be elusive. But C_c does not follow from P_c alone. It only follows if P_c is associated with T_1 and T_2. Therefore, the three classical approaches appear to be based on the two tenets T_1 and T_2, but these two tenets are questionable.

3.2. The first tenet defeated: the definition of a term does not necessarily preexists the act of defining it

In order to establish that T_1 is false, the example of the term “art” is peculiarly useful. This is meant to convey neither the idea that biodiversity is an aesthetic notion, nor the one that conserving and defining biodiversity are artistic endeavors. The analogy is limited to the role played by these notions in our language.

In a sense, we all know what “art” means, but the question of a precise definition of the term is notoriously indecidable. Several approaches have been developed. They share some similarities with the approaches of biodiversity studied above, but are not exactly identical.

Purely *empirical* approaches attempt to define art by identifying what people typically call “art” (Kennick 1958, Weitz 1956). *Essentialist* approaches claim they can identify once and for all the essence of art (Danto 1981). Lastly, noticing that innumerable heterogeneous human activities involve art, *demystifying* approaches claim that there is no such thing as art in general (Gaut 2000).

The history of art theorizing illustrates the failure of all these three classical approaches: artists usually respond to each and every definition of art by modifying their artistic practices (Pignocchi 2012). Indeed, a given definition can shed light on hitherto neglected aspects of art and thereby launch creative processes aimed at illustrating or contradicting it, and new definitions are needed to make sense of the emerging result. In that sense, practices and corresponding theories co-evolve in possibly endless parallel evolutions. Contrary to what T_1 claims, the definition of the term is not independent of theorists' attempts at defining it: it is not preexisting. However, the fact that no definitive definition of art may ever be reached does not mean that trying to define "art" is wishful thinking. Quite the contrary, it means that striving to define art is taking part in the construction of art itself (for another example, illustrating that a rejection of T_1 is not confined to aesthetic issues, see Dworkin's (1998) approach to law).

3.3. The second tenet defeated: defining a term is not necessarily a matter of identifying an entity

It might seem at first sight that a term cannot be meaningful at all if it cannot be defined as referring to a preexisting entity. However, some very common terms, undoubtedly meaningful, do not function like this. The term "hello" is an apt example. If one were pressed to define this term, it would be pointless to strive to identify an entity to which the term would refer. One had better try to identify the role played by the term in our language: "hello" is used to greet, and there is nothing more to say to define the term (Searle 1969).

However, this example of the term “hello” might seem irrelevant to an inquiry into the meaning of “biodiversity” because, contrary to “biodiversity”, it is not a noun. But an approach paralleling the one to “hello” proves to be fruitful in the case of numerous nouns as well. Think about the noun “legitimacy”: trying to identify the role it plays in our language is undoubtedly a more promising route to define it than pretending to identify an entity to which it would refer.

This approach to definitions, according to which defining a term is first and foremost a matter of identifying what the term is useful for (rather than what it refers to), originates in the work of Wittgenstein (2001) and Austin (1975), and has been developed by the school of ordinary language philosophy (Soames 2003) and other so-called pragmatic linguists (Szabò 2006).

Identifying the role played by terms like “hello” in our language is obviously easier than identifying the role played by terms like “biodiversity”. However, the philosophical arguments articulated above show that rigorously defining the term “biodiversity” is not necessarily identifying an entity (be it a set a objects, processes, properties or magnitudes) to which the term would refer nor providing for a definitive formula. It is rather scrutinizing what kind of role the notion plays in our language, assessing if it is useful at all, and if it is, eventually showing what it is useful for. Since, in this approach, using the term “biodiversity” and trying to define it are taking part in the construction of the concept itself, we call this approach “constructivist”.

4. The key-question of the constructivist approach: what is the general notion of biodiversity useful for?

In order to illustrate how our constructivist approach works and how useful it can be, let us see what help it can provide in a practical example of valuation: the fishery in the Aleutian marine ecosystem studied by Estes et al. (1998), Finnoff & Tschirhart (2003) and Eichner &

Tschirhart (2007), among others (Fig. 2). According to standard economics, fisheries and associated ecosystems face several problems of externalities (Perrings 2009). In what follows, we will focus on one of them: the risk that repercussions of the overexploitation of one resource are not being taken into account in the determination of consumers' behavior. In the example chosen, human consumers buy items of one species (pollock) on markets and thereby indirectly impact other species due to interactions in the ecological system. This indirect impact can in turn alter the provision of various ecological services. Most variants of this problem, and the alleged solutions provided by the standard economic approach, are articulated in terms of "biodiversity" in most publications. The first step of the constructivist approach is to ask if this formulation makes any difference. If it does, this means that the term "biodiversity" plays a role (or, equivalently, has a function) in these discourses, and the second step of a constructivist approach is then to use this function. If it turns out that this two-steps procedure is feasible and can be generalized, just like we illustrate a definition of "hello" by greeting people, we will have produced a definition of "biodiversity" by showing what the general notion of biodiversity is useful for.

4.1. The first step of the constructivist approach: ascertain whether the term has a function and if so, identify it

According to standard economics, if ecologists and economists manage to condense all the information contained in the ecological network into an increase of the price of pollock (for example through taxes imposed on harvesting activities or a cap on harvest), demand will drop, overfishing will cease, kelp will recover, etc. (Finnoff & Tschirhart 2003). This conclusion could be articulated in economic terms alone, but as a matter of fact economists often make the effort to translate it in terms of "biodiversity".

If either the conventionalist or the unit-and-difference approach were true, as explained above, it would mean that, when an economist says “biodiversity”, what she or he has in mind is entirely determined by purely economic concepts (utility functions, social planner’s optimization and the like), and is completely different from what an ecologist has in mind when using the same term. In its application to the economic problem at issue here, this idea is patently implausible. Indeed, economists would not bother translating their results in terms of “biodiversity” if the only expected result were to translate the message from one jargon accessible only to economists, to another jargon just as much esoteric. If economists so forcefully insist on translating their results in terms of “biodiversity”, it can only be because they tacitly claim that their results *are relevant* for other biodiversity sciences. This point, regrettably ignored by the classical approaches to the general definition of biodiversity (including the most promising unit-and-difference approach), can be generalized to all discourses articulated in terms of “biodiversity”. As soon as one expresses or translates one’s disciplinary discourse in the general terms of “biodiversity”, one claims (or at least one is committed to claim) that what one says is relevant beyond one’s own disciplinary borders—relevant for all the other disciplines making, as a matter of fact, similar credible claims.

But a claim (emitted by one or several speaker(s)) is always *directed at* one or several hearer(s), and *is predicated on* its acceptability by this audience (Habermas 1981). For example, if speaker S utters “I am the Commander of this crew”, this utterance cannot qualify as a claim properly speaking if S is alone in the desert or if he is one ordinary seaman among others in the crew he speaks to: in such cases S’s utterance is a vain one (or a joke). It cannot be a claim properly speaking unless S utters it before a crew that is liable to accept it (which can be the case, e.g., if the real commander is no longer able to honor his duty and S is the second-highest ranked official). A more comprehensive reformulation of the constructivist idea is therefore: for the speaker (or writer), the function of the term “biodiversity” is to claim general relevance of his results; for the hearer (or reader or analyst), it is to critically assess the credentials of this purported relevance of the results.

4.2. <u>The second step of the constructivist approach: use the function of the term</u>

If implemented in the case of ecological-economic modeling, the constructivist approach thus holds that using the term "biodiversity", and thereby constructing its definition, is asking the question: do the results of ecological economic models qualify as relevant, beyond economics alone, to all biodiversity disciplines?

4.2.1. Disciplinary assumptions

One important issue to assess this putative relevance is whether the basic assumptions postulated by these models can be taken for granted in a more general context. Typically, these studies postulate that it is possible to achieve a perfect knowledge of the ecological mechanisms and that the behavior of the economic agents can be perfectly foreseeable (and modeled by a utility function). One problem created by these assumptions is that the models based on them prescribe to concentrate and confine all the relevant information into prices, which in turn incites consumers to think only about their own money. Take for example the detrimental effects of the production, commercialization and usage of marketed products on insect pollinators and the ensuing ecological consequences (Gallai et al. 2009). If all these detrimental effects were already integrated in their price, there would be no need for consumers to think about anything else than prices: seeing that prices are high, they would eschew buying these products and the detrimental effects would thereby be avoided. In this scenario, consumers would not need to know that the reason why the price of a given product is high is that it has detrimental effects on pollinators, and it would therefore be unnecessary for ecologists and economists to invest time and money to diffuse ecological information.

Similarly, consumers would not need to adapt their preferences to the environmental constraints and to organize their decision-making in an intelligent, long-term horizon (Singer 2004).

If only the prospect of ever being able to integrate into prices *all* the ecological information, concerning *all* the ecological mechanisms *all* around the world, were a credible one, it might be worth investigating this strategy. Unfortunately, it is widely acknowledged that this prospect is an unachievable, fanciful one (Barbier 2000): in the real world, perfect knowledge is unachievable even for the best scientists and prices therefore cannot integrate *all* the ecological information. The optimum calculated by the model being unachievable, the latter faces a so-called "problem of the second best" (Lipsey & Lancaster 1956-57): there is no logical guarantee that acting as if the optimum were achievable (that is to say: endorsing the standard assumptions and thereby promoting the creation of incentives for consumers to develop a self-centered, short-sighted and uninformed behavior) will be conducive to the second best result. It is possible that achieving the second best requires a completely different strategy, for example that consumers precisely do *not* behave in a self-centered, short-sighted and uninformed way. Therefore, although the standard economic approach is undoubtedly valid within the framework defined by its disciplinary assumptions, it could have very destructive effects if other biodiversity disciplines were to mistake the standard economic results as being applicable to the real world (whereas, due to the problem of the second best, they are in fact only applicable to fictitious worlds where the optimum is achievable).

When using the term "biodiversity" in presenting their results, economists claim that their results are relevant outside their discipline; but using the term "biodiversity" as critical readers of these economic arguments, we see that this claim must be rejected. This example thus illustrates that taking seriously the implicit claims of generality encapsulated in the term "biodiversity" and critically assessing its credentials is a very rewarding exercise, because it shows why disciplinary approaches can fail to solve integrated, interdisciplinary biodiversity issues all by themselves, and where and why they are flawed. As additional illustrations of this heuristic role we proceed by showing that the constructivist approach can shed light on three crucial components of the biodiversity issues presented in the fishery example that are obscured by the standard economic approach.

4.2.2. What counts as a solution?

What if consumers were willing to pay the increased price calculated according to standard economics, and thereby go on impacting the environment? Clark (1999) showed that, if this possibility is admitted, it can be economically rational to exploit species to extinction. However, the latter case is ignored without justification in most current models. For example, Eichner & Tschirhart (2007) simply state, in a foot-note, without any explanation: "[t]he question of optimal extinction is beyond the scope of the present paper" (note 15, p. 744). If "optimal extinction" is a solution to the management problem under standard economics, why then does it ignore it? The constructivist approach suggests that the reason is that, in practice, standard economics theorists vaguely see that optimal extinction cannot qualify as a solution in the context of an interaction between economics and other biodiversity disciplines. The very fact that these studies present themselves as economic studies *of biodiversity* constrains the kind of result that they can present as genuine solutions more strongly than if they would simply present themselves as economic studies of entities that happen to be independently called "biodiversity" by biologists.

4.2.3. The moral underpinnings of valuation methods

Conveniently enough, the neglect of optimal extinctions also makes it look as though ecological-economic modeling is a purely scientific, value-neutral exercise. But as soon as one accepts that such problems might empirically arise, it becomes clear that standard economics makes two incompatible moral claims. On the one hand, standard economics postulates that ecological and economic experts are justified to manipulate prices, and thereby people's behavior. This claim is undeniably a moral one, and consistently maintaining it would imply that experts should be the only ones to take the rein of ecosystem management. But supporters of standard economics forcefully reject this implication, since their models are based on the idea that, so long as ecological consequences are integrated in prices, consumers should be authorized to act freely on markets. In that sense, they admit that experts cannot simply take all the decisions on behalf of the larger society (Estlund 2008). At the very least, economic methods have to admit the moral status of these premises, and to clarify them.

4.2.4. Qualitative information and the formation of preferences

By positing that consumers should act freely on markets, standard economics thus assumes that consumers' and citizens' preferences must somehow be taken into account and respected (Sen 1973). This undeniably moral premise is, in one form or another, shared by the vast majority of the current philosophical (Kymlicka 2002) and economic (Sen 2008) literature, and is hence arguably not very controversial. Our critical examination of the application of standard economics to the fisheries issue however suggests that the internal coherence of ecological-economic models in their endorsement of this premise is doubtful. Indeed, if one decides to respect preferences, one has to make sure that the preferences purportedly respected are conveniently formed. Ecological-economic models will therefore remain internally incoherent so long as they do not investigate whether, in addition to or instead of the integration of ecological information into prices, the very construction of preferences requires that consumers understand the concrete ecological consequences of their acts, evaluate them with regard to the values they hold, and thereby make reflexive choices (Sagoff 2008, Meinard & Grill 2011).

Altogether, our critical analysis in this section does not mean that economics is irrelevant to the resolution of biodiversity issues. It simply shows that, as they stand, these approaches do not live up to the expectations aroused by the formulation of their results in terms of "biodiversity". But if standard economists take seriously and endorse our constructivist approach, this demonstration of their failure can turn into the first step of a fruitful critical dialog. Indeed, a simple clarification and open admission by economists of the various presuppositions of their approaches would already considerably strengthen the quality of collaborations between economists and biologists. This could be the first step towards collaborations through which economists and biologists could participate in a reorientation of economic models liable to make the latter more relevant to the resolution of environmental issues.

Besides, although our explanation in this article has been centered on an example of interactions between economics and ecology, the logic elaborated above is applicable to the other interdisciplinary interactions as well. For example, just like economic studies, anthropological studies presenting themselves as studies of biodiversity thereby implicitly claim that they are relevant to the other biodiversity studies, outside anthropology. Contrary to economic studies, most of these studies openly acknowledge that they are not ethically neutral, for example, when they (more or less openly) promote an approach in which local stakeholders take the reins of environmental management (e.g. Mougenot 2003). But they do not investigate whether, and to what extent, their specific ethical stances can constrain the possibility for them to participate, on a par with ecological studies, to the resolution of common problems.

And what is true of interactions between disciplines is also true of interactions between scientists and political decision makers. According to our constructivist approach, these interactions could be considerably enriched if, instead of postulating that “biodiversity” must refer to a supposedly clearly identified entity, both scientists and decision makers were to admit that talking about “biodiversity” to one another commits them to engage in a collaborative process of clarification of the problems they wish to solve.

5. Conclusions

Many authors are prone to emphasize the interdisciplinary status of the concept of biodiversity, or to stress that it is a “bridge concept” (Norton 2008) liable to link scientific practices and public discourse. But the possibility for this notion to be a bridge concept requires a comprehensive explanation. Our explanation in this article is based on the idea that the term “biodiversity” does not refer to a pre-existing entity: its meaning is given by its function in our language, and this function is not primarily a referential one. The function of the term "biodiversity" is the following: it is a term used to present results, ideas and projects in such a way as to claim that they are relevant, beyond their home discipline, to all the disciplines and discourses that happen to use the term. In this approach, biodiversity is a bridge concept indeed, because its function in our language is such that, using the term “biodiversity” commits the user to claim, and to be able to redeem her or his claim, that what she or he says about biodiversity is relevant for the other users of the term.

When an ecologist is done with the purely ecological part of the study of an ecological-economic system, the easiest way for her or him to proceed is to hand over the case to an economist who will study it independently. In our rationale, the interdisciplinary study of biodiversity is not that kind of relay race. It is rather an attitude that consists in taking advantage of insights from as many disciplines as possible to shed light on basic problems or presuppositions in order to constructively criticize them.

This form of interdisciplinarity, that is according to our logic a crucial part of the agenda of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), is not an easy task. It involves tackling the notion of biodiversity in a truly integrative way, critically assessing the scientific credentials of various accepted methods, and confronting the novelty of the environmental challenges. Our approach hence suggests that biodiversity sciences have a philosophical and societal relevance, and that biologists should not be afraid to take a more affirmative stance and to engage more vigorously in the resolution of biodiversity issues—be it by critically appraising current valuation methods, participating in the diffusion of ecological knowledge, invigorating philosophical and political debates, or engaging in the creation of relevant institutions.

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Property	Formal definition
Reflexivity	For all a, $X^a \geq X^a$
Transitivity	For all a, b, c, if $X^a \geq X^b$ and $X^b \geq X^c$ then $X^a \geq X^c$
Indifference	For all i, j, {i}~{j}
Monotony	For all i, j, if i and j belong to the same species then {i}~(i,j), otherwise {i}<(i,j)
Independence	If neither X^a nor X^b contain i, then $X^a > X^b$ if and only if X^aU{i}>X^bU{i}

Table 1

i, j are individuals. X^a, X^b, X^c are samples to be compared. ">" stands for "is strictly more diverse than", "~" for "is just as diverse as", and "≥" for "is at least as diverse as".

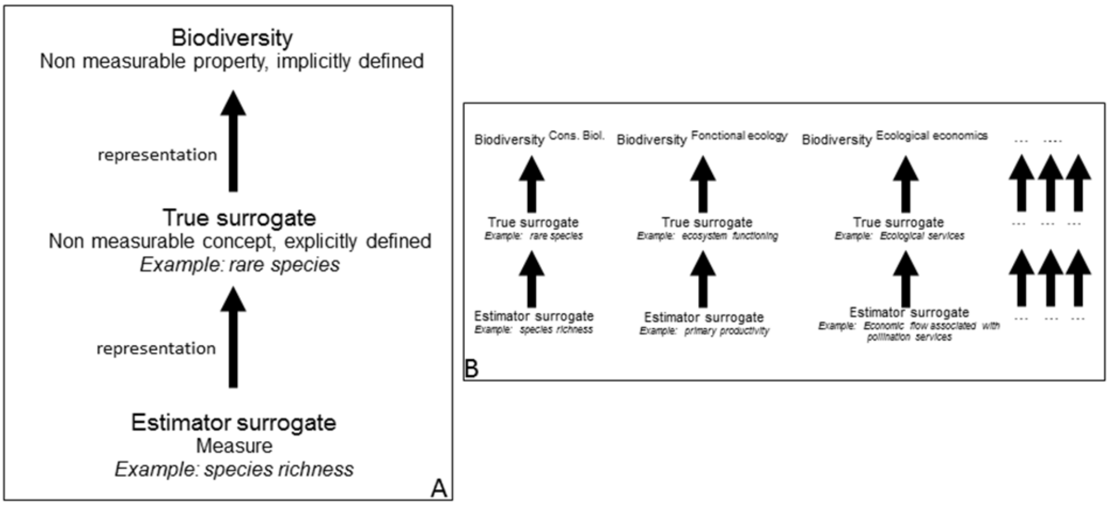

Figure 1. A. Surrogacy relations according to the conventionalist approach. B. Generalization to other biodiversity sciences (this involves calling “surrogates” some concepts usually not considered to be surrogates of biodiversity, e.g. ecosystem services).

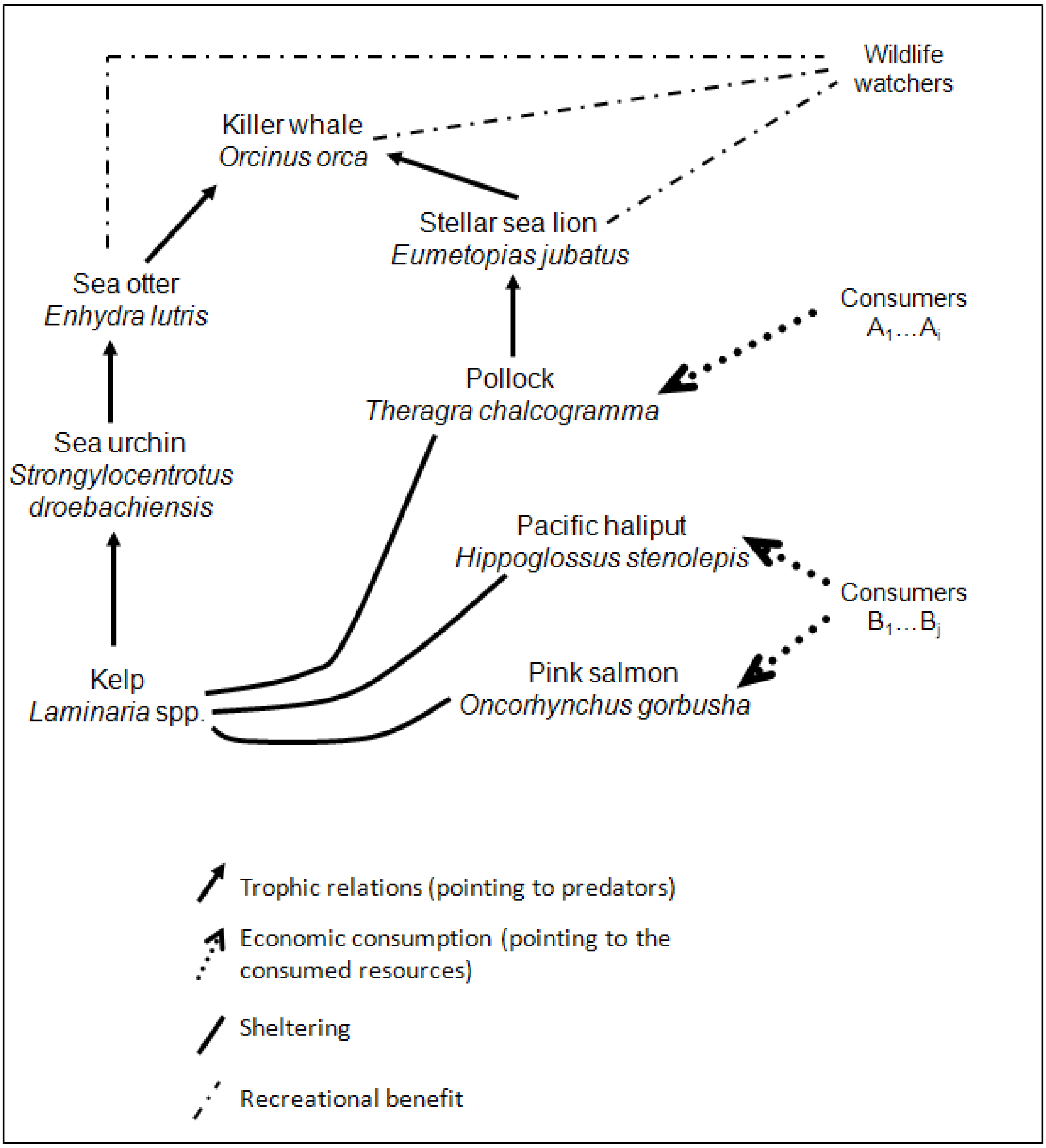

Figure 2. Consumers A_1... A_i consume pollocks. Overexploitation of pollocks leads to a decrease of their predators stellar sea lions. As a consequence, killer whales consume sea-otters, themselves consuming sea urchins, themselves grazing on kelp. Kelp being nurseries for innumerable fish species consumed by human consumers A_1... A_i and B_1... B_j, overfishing pollock has an indirect impact on all these consumers.